



# National Transportation Safety Board



Photo by Scott Germain

## P-51D The Galloping Ghost

September 16, 2011

Reno, NV

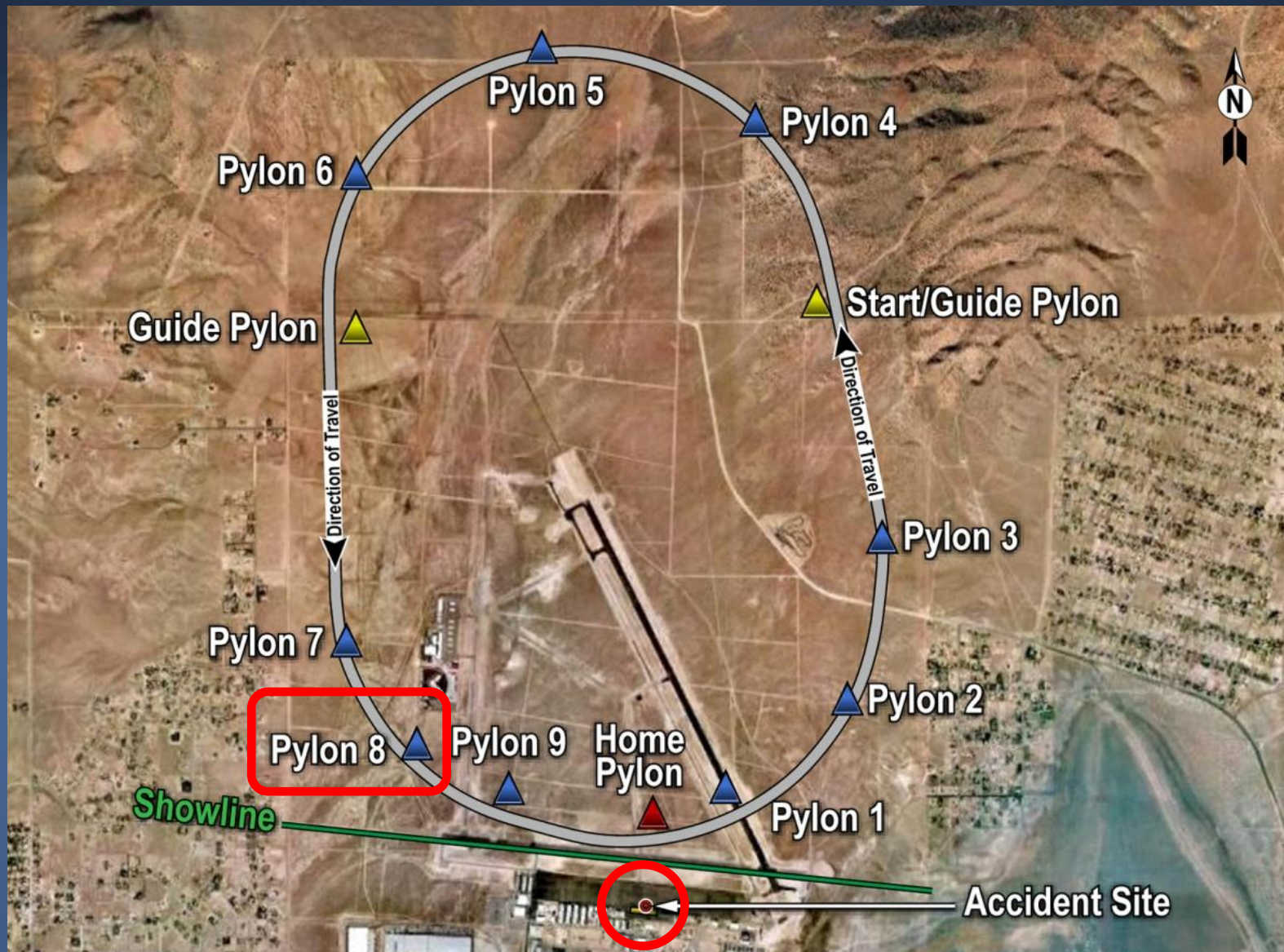
Earl Weener, PhD  
Board Member

University of Michigan November 9, 2012

# Accident Summary

- September 16, 2011
- 1625 Pacific daylight time
- Modified experimental P-51D, “The Galloping Ghost”
- Collided with ramp
- NCAR Unlimited Class Gold Race
- Pilot and 10 spectators fatal
- At least 64 spectators injured; at least 16 serious

# Unlimited Race Course - 2011



# Parties to the Investigation

- Federal Aviation Administration (FAA)
- Reno-Tahoe Airport Authority (RTAA)
- Reno Air Racing Association (RARA)
- National Air-racing Group (NAG)  
Unlimited Division
- Aerodynamic Consulting, LLC
- RCAT Systems

# NTSB Staff

- Howard Plagens
- Josh Cawthra
- Clint Crookshanks
- John Clark
- Dennis Crider
- Marie Moler
- Dan Horak
- Mike Bauer
- Chris Babcock
- Kelly Nantel
- Terry Williams
- Nicholas Worrell
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- Cathy Gagne
- Dr. James Duncan
- Paul Suffern
- Derek Nash
- Elias Kontanis
- Max Green
- Eric Emery
- Michael Crook
- Jane Terry
- Jeffrey Marcus
- John Whitener

# Accident Video



# Accident Video – Half Speed



# Accident Sequence

- Performance study
- Video study
- Image study
- Correlated telemetry, photos, and video
- Left roll upset at 1624:28.9



**Right Elevator  
Trim Tab**

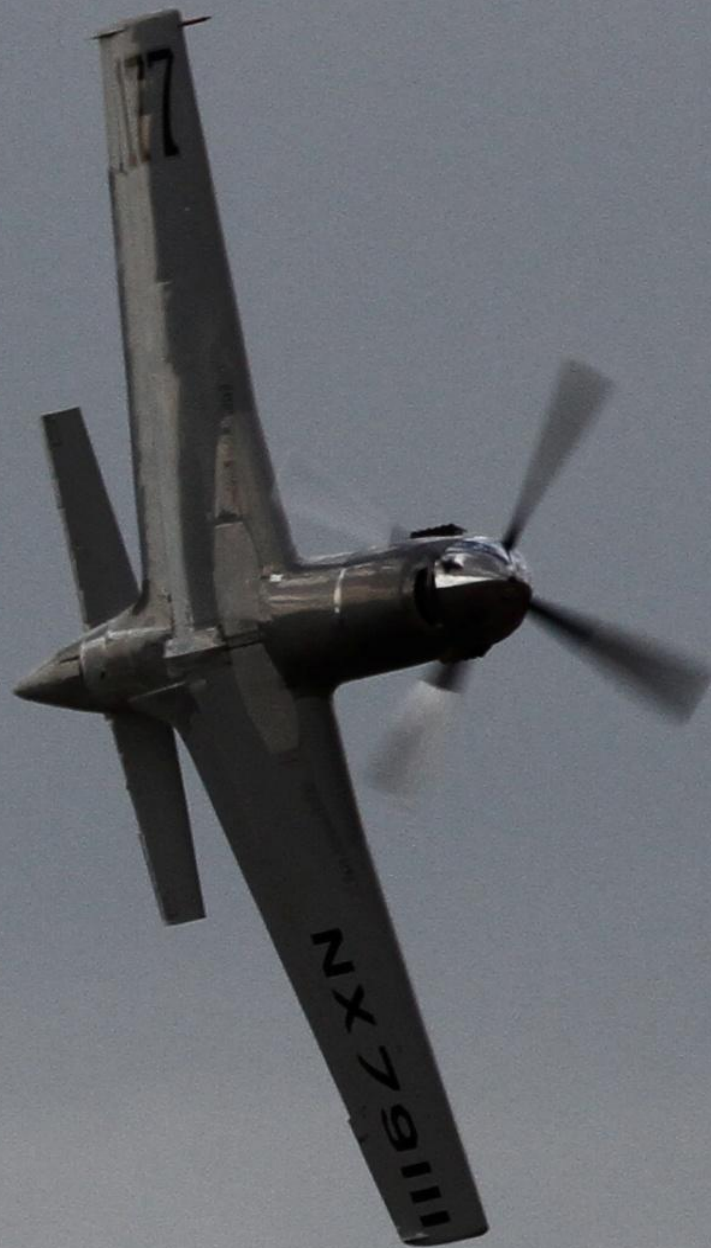
**Left Elevator  
Trim Tab**

**Left Aileron**

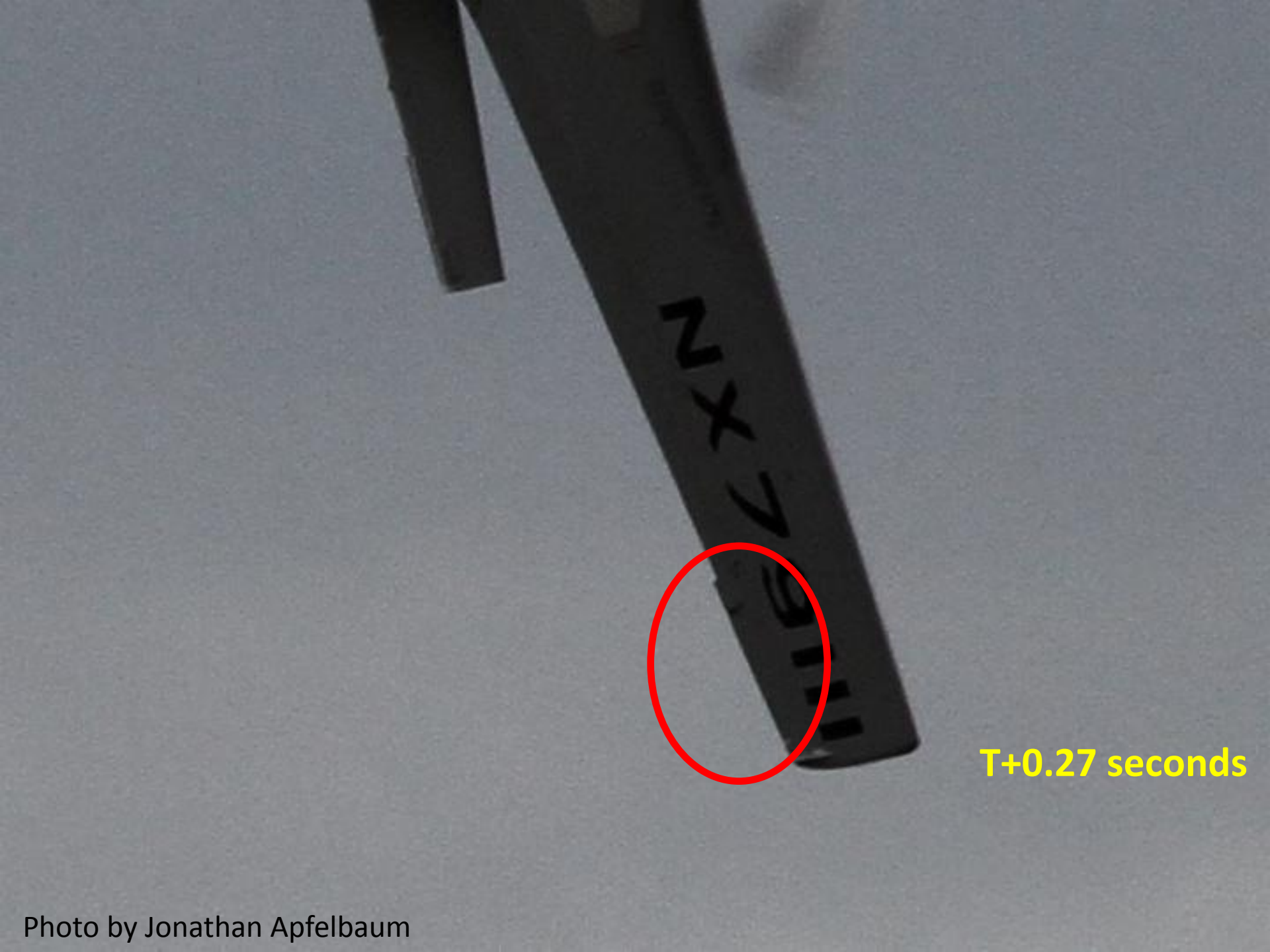
**T-0.25 seconds**



T+0.14 seconds



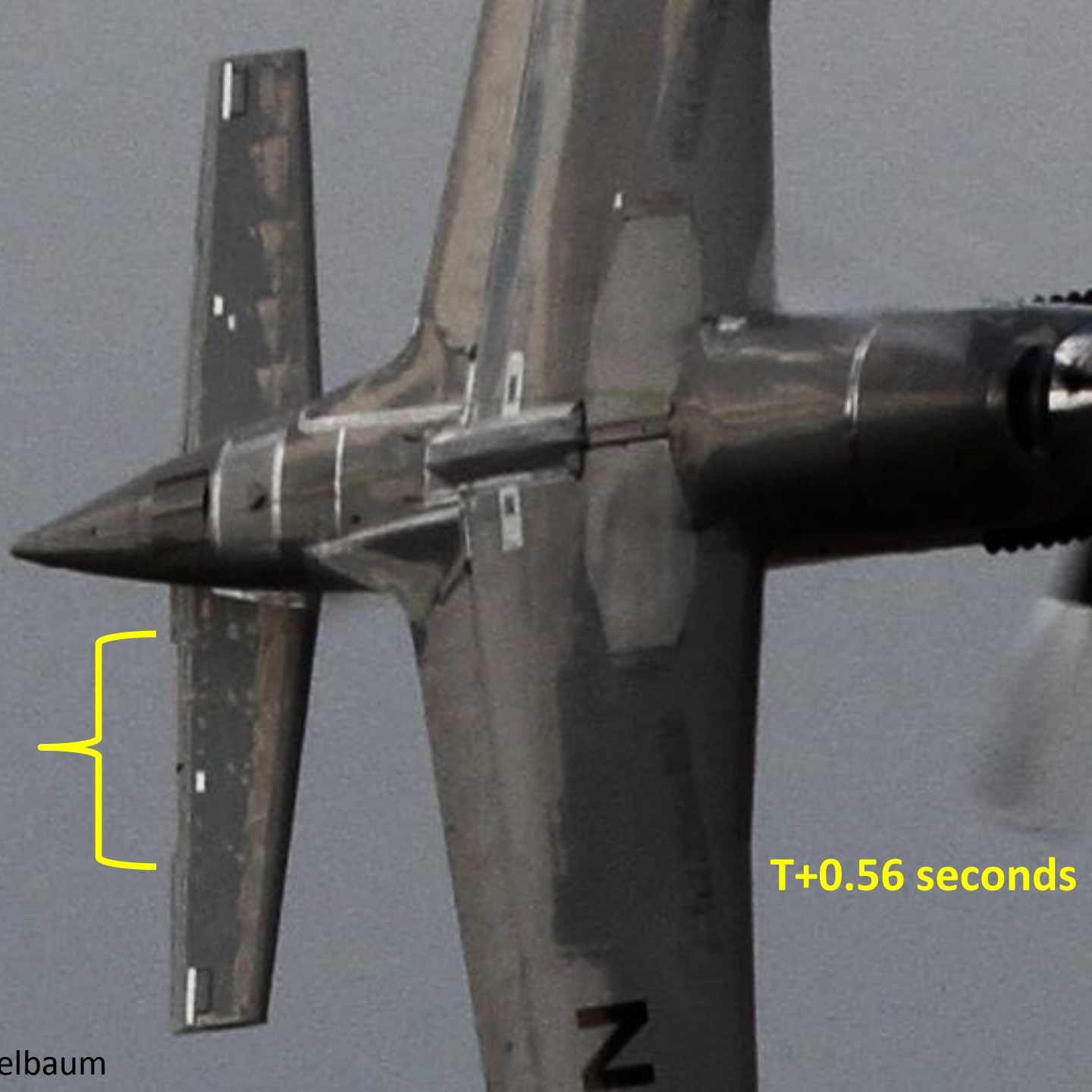
**T+0.27 seconds**



T+0.27 seconds



**T+0.56 seconds**



T+0.56 seconds



**T+0.70 seconds**



**T+1.30 seconds**



T+1.30 seconds



T+1.44 seconds



T+1.44 seconds



T+3.4 seconds



Photo by Frank Ranney



Photo by Frank Ranney



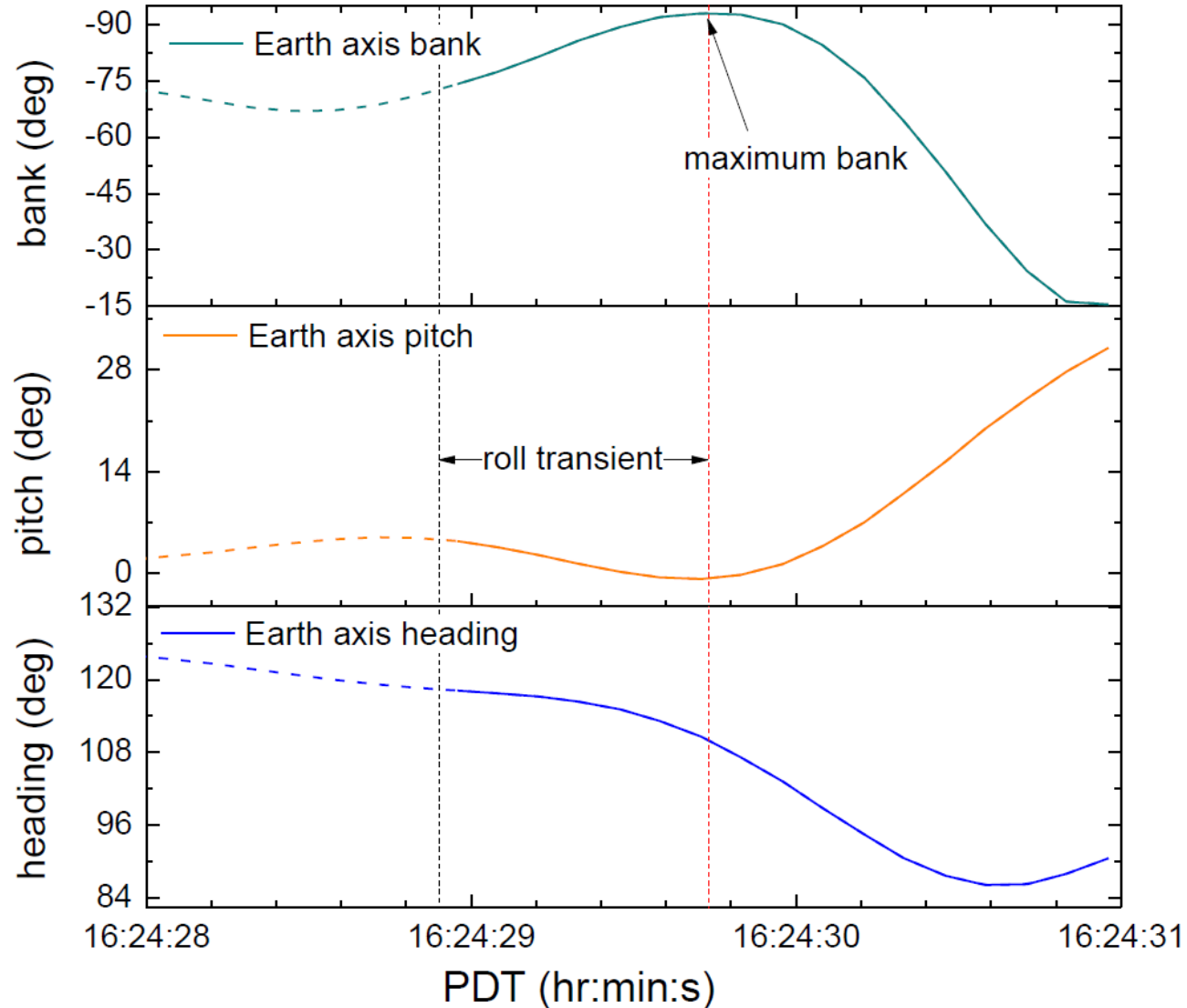
Photo by Frank Ranney



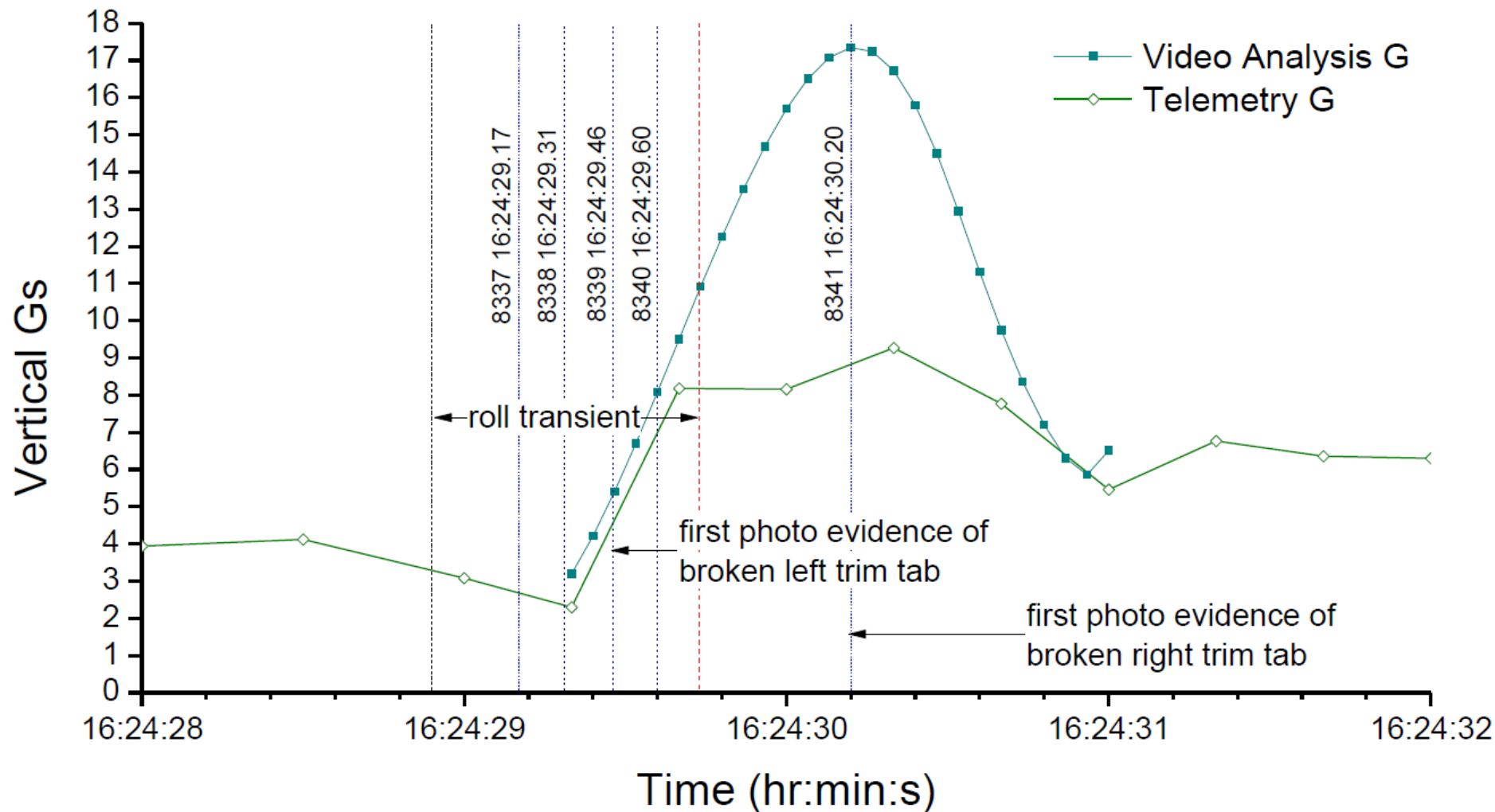
**T+4.6 seconds**



# Airplane Motion



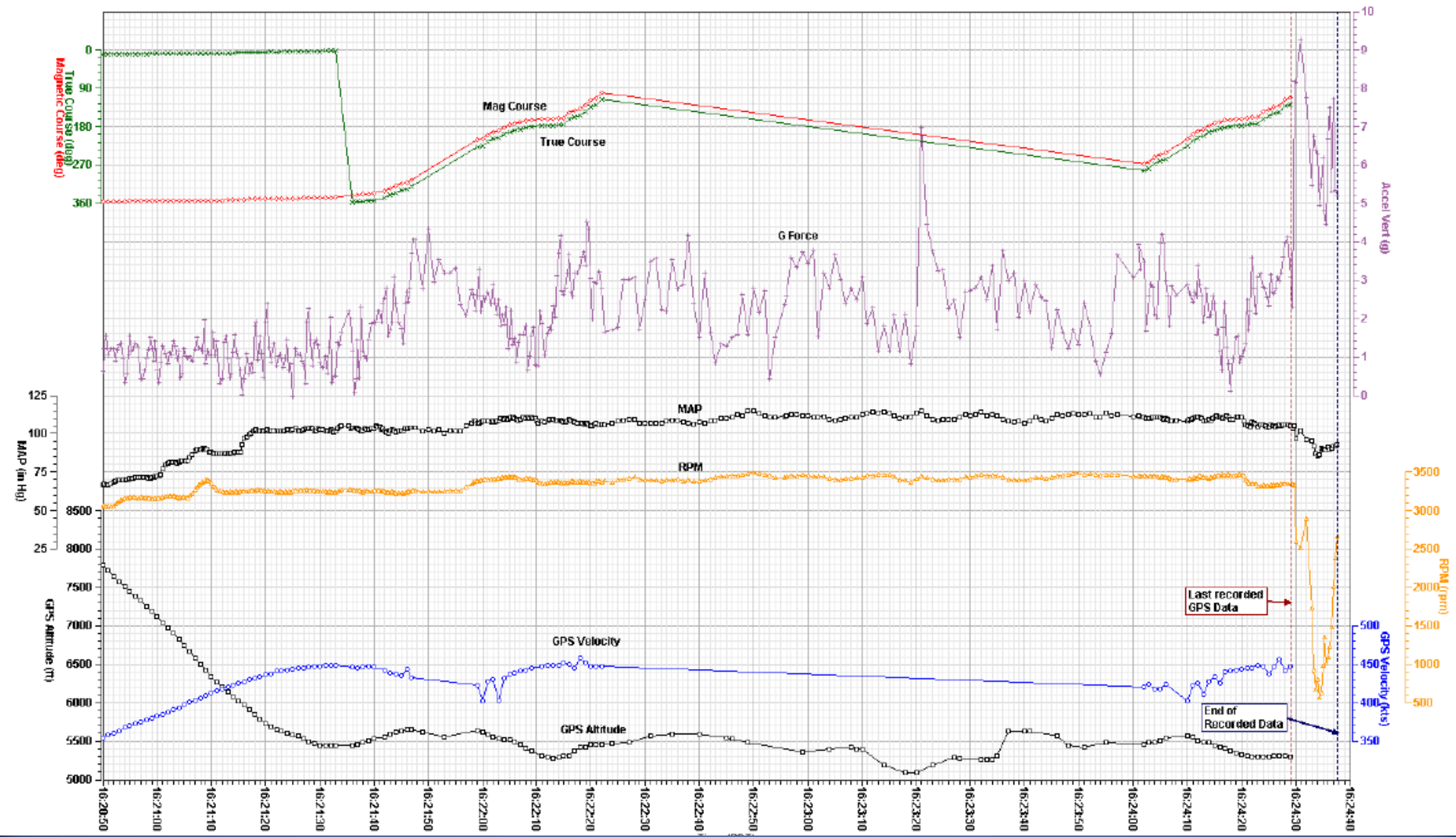
# Vertical Load Factor



# North American P-51D Racer, N79111

Location, Date: Reno, NV, 09/16/11

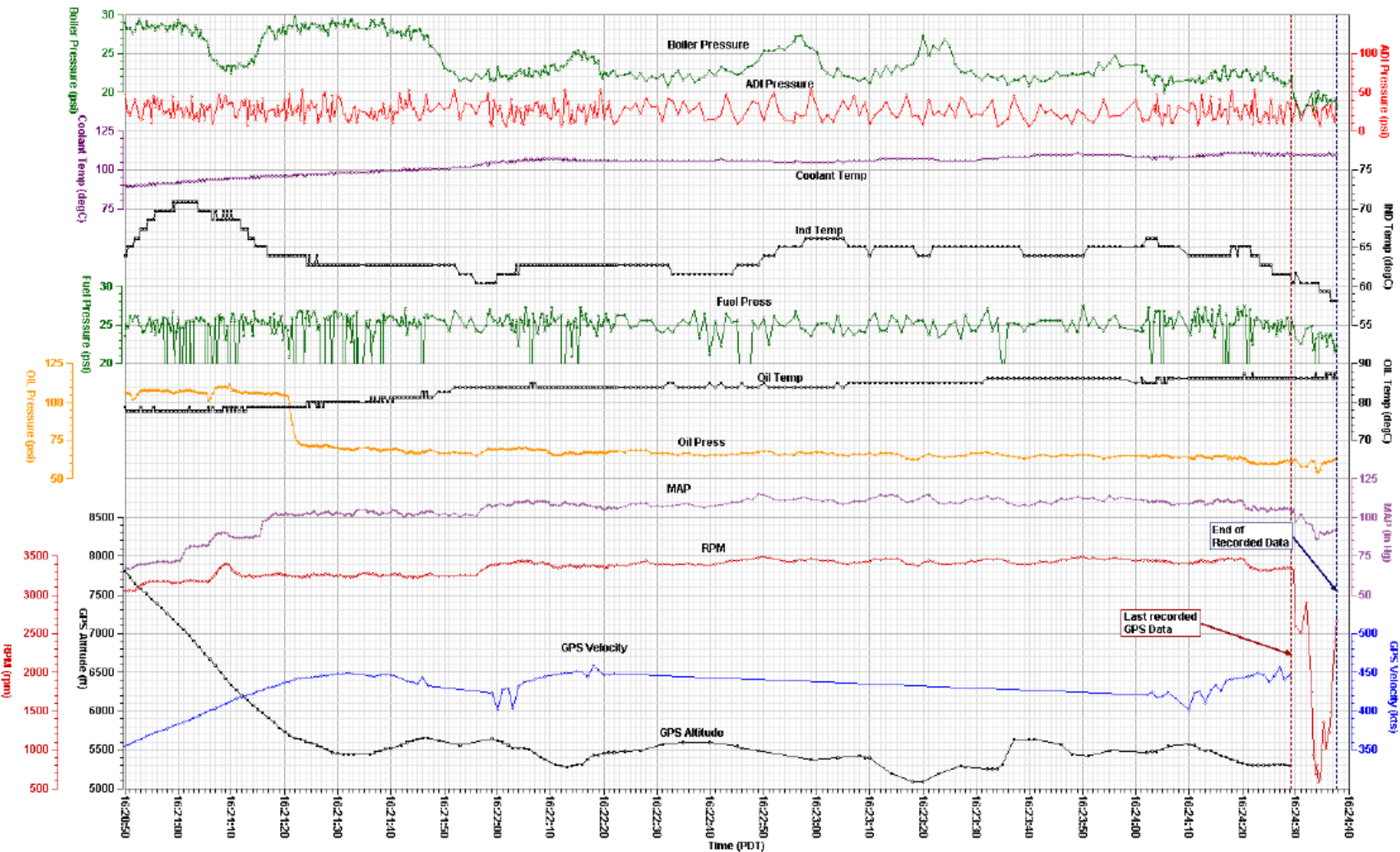
NTSB No. WPR11MA454

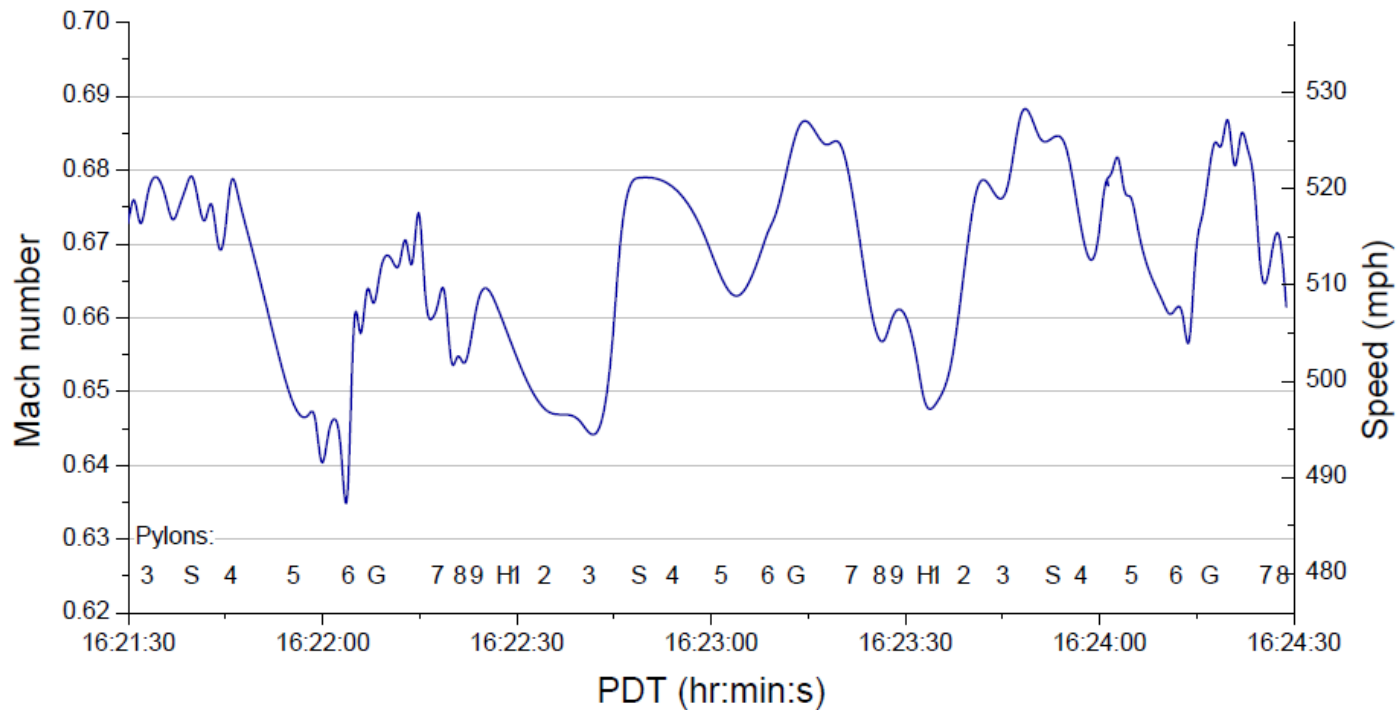
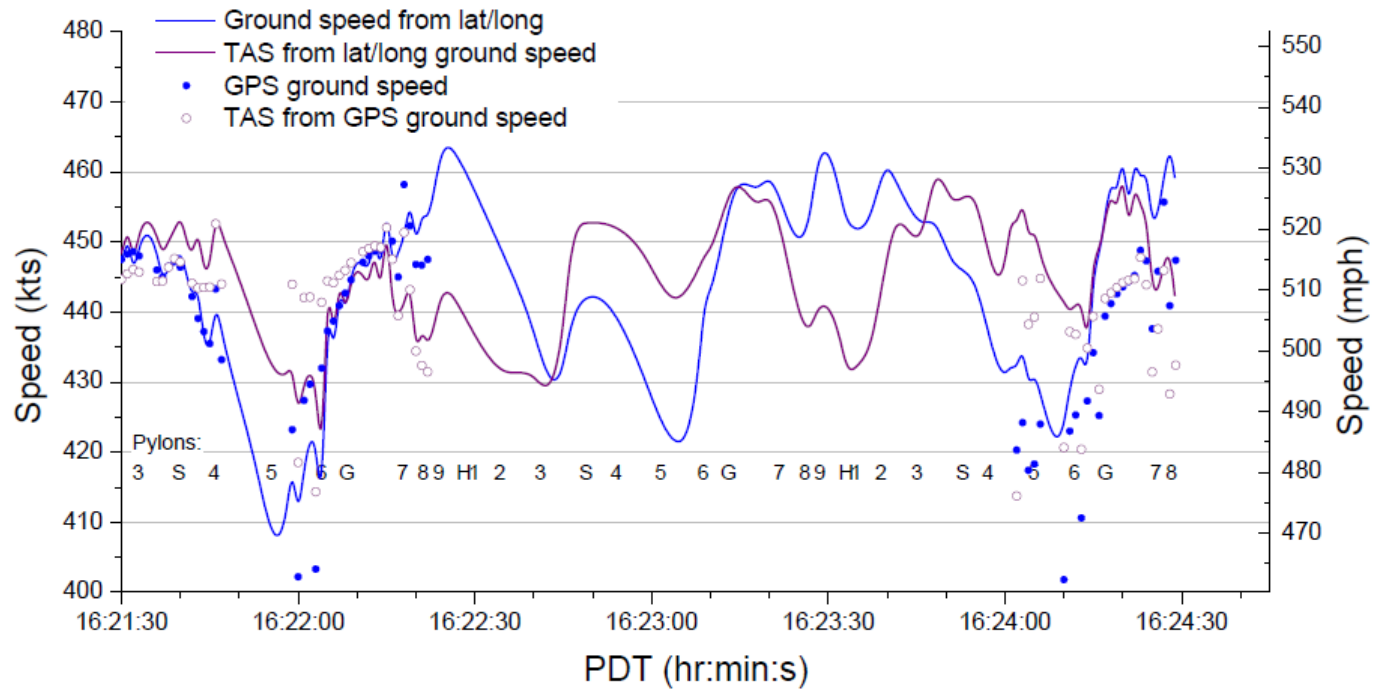


# North American P-51D Racer, N79111

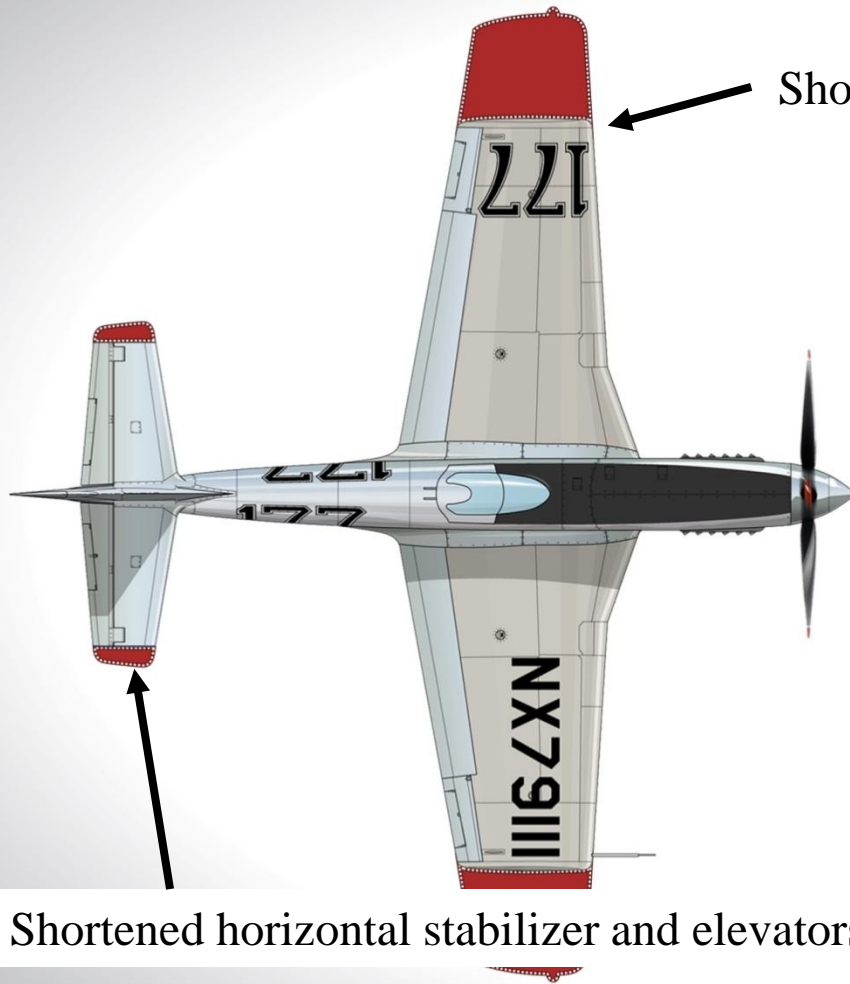
NTSB No. WPR11MA454

Location, Date: Reno, NV, 09/16/11





# Structural Modifications



Shortened horizontal stabilizer and elevators

# Structural Modifications

- Changed horizontal stabilizer incidence
- Changed vertical stabilizer incidence
- Installed solid engine mounts
- Installed boil-off cooling system
- Reduced drag and gross weight

# Assembly



Photo by Scott Germain

# Flight Control Modifications

- Reduced elevator inertia weight
- Increased elevator counterweights
- Increased rudder counterweight
- Fixed and faired right elevator trim tab
- Electrically actuated left elevator trim tab
- Filler and paint on elevator trim tabs
- Modifications increased pitch sensitivity
- Pitch trim system more susceptible to flutter

# Elevator Inertia Weight



Photo by Scott Germain

# Elevator Counterweights



Left



Right

# Overbalanced Elevator



Photo by Scott Germain

# Trim Control

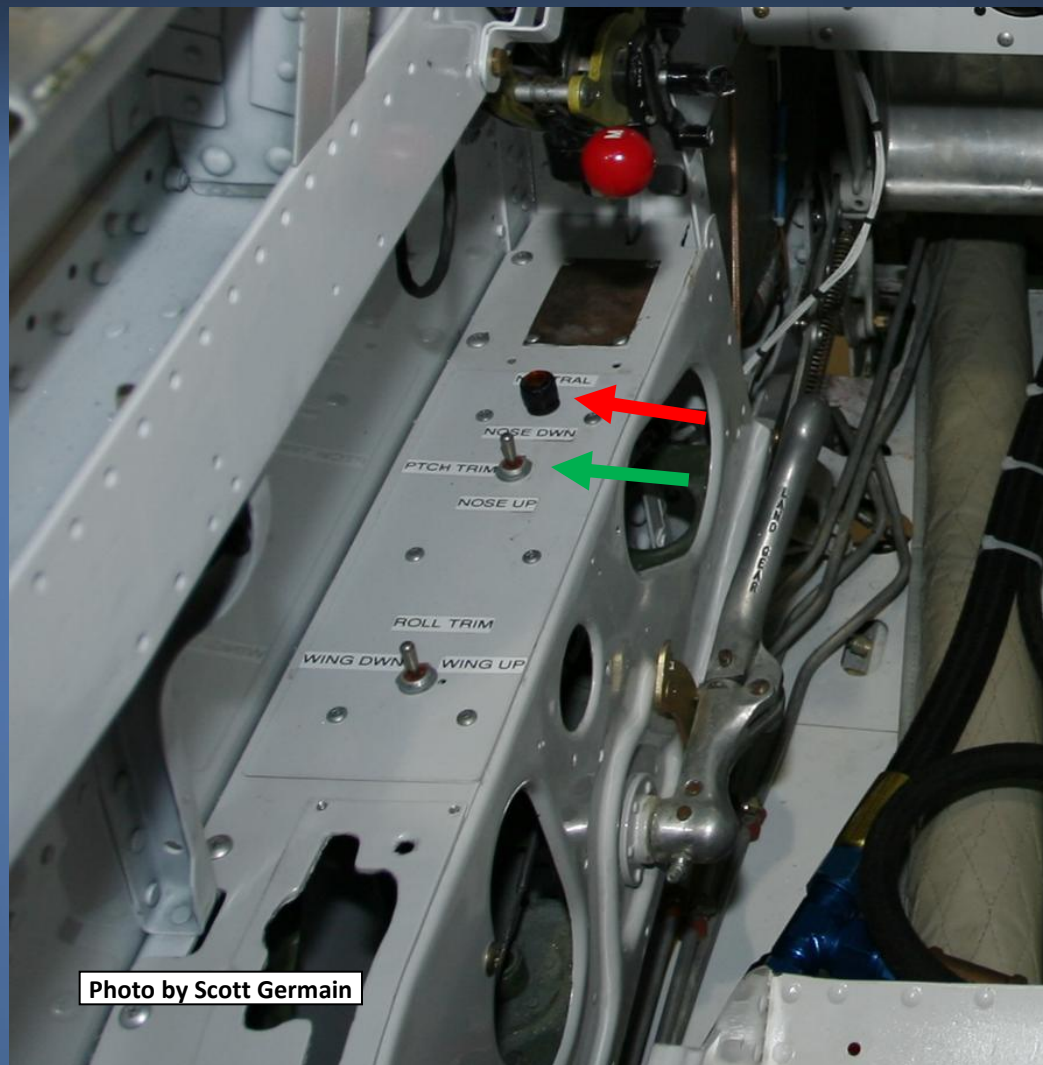
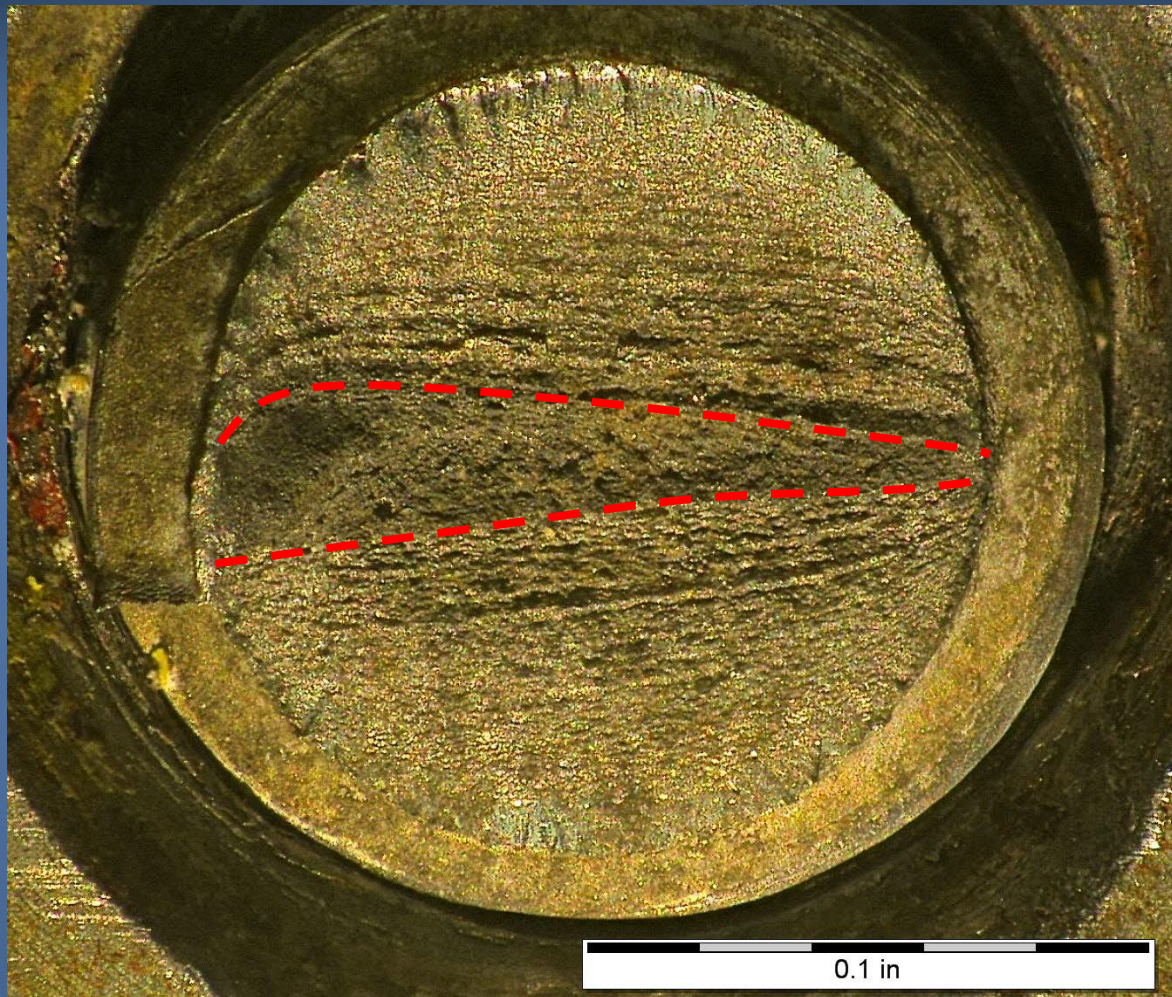


Photo by Scott Germain

# Left Elevator



# Left Inboard Attachment Screw



# Left Tab Link Assembly



# Left Trim Tab Support



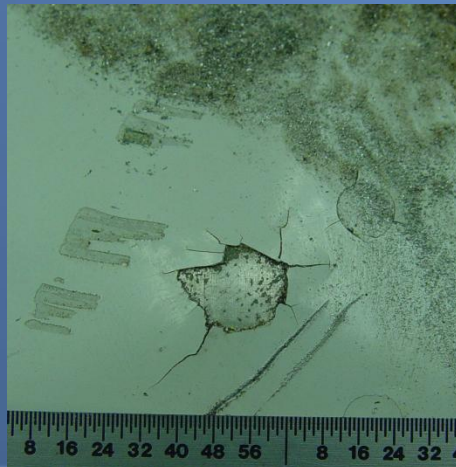
# Right Elevator



# Fixed Right Trim Tab



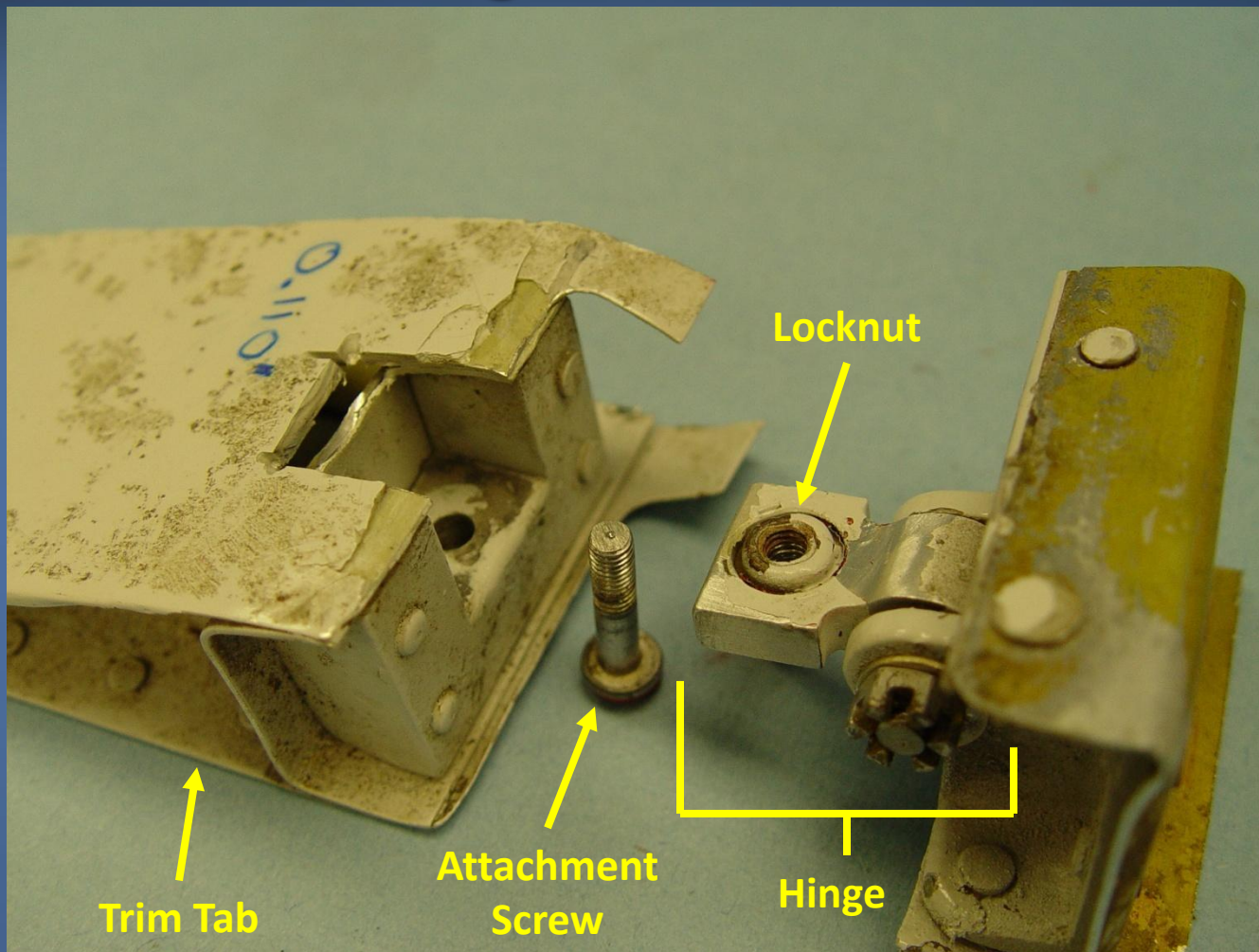
# Right Tab Link Assembly



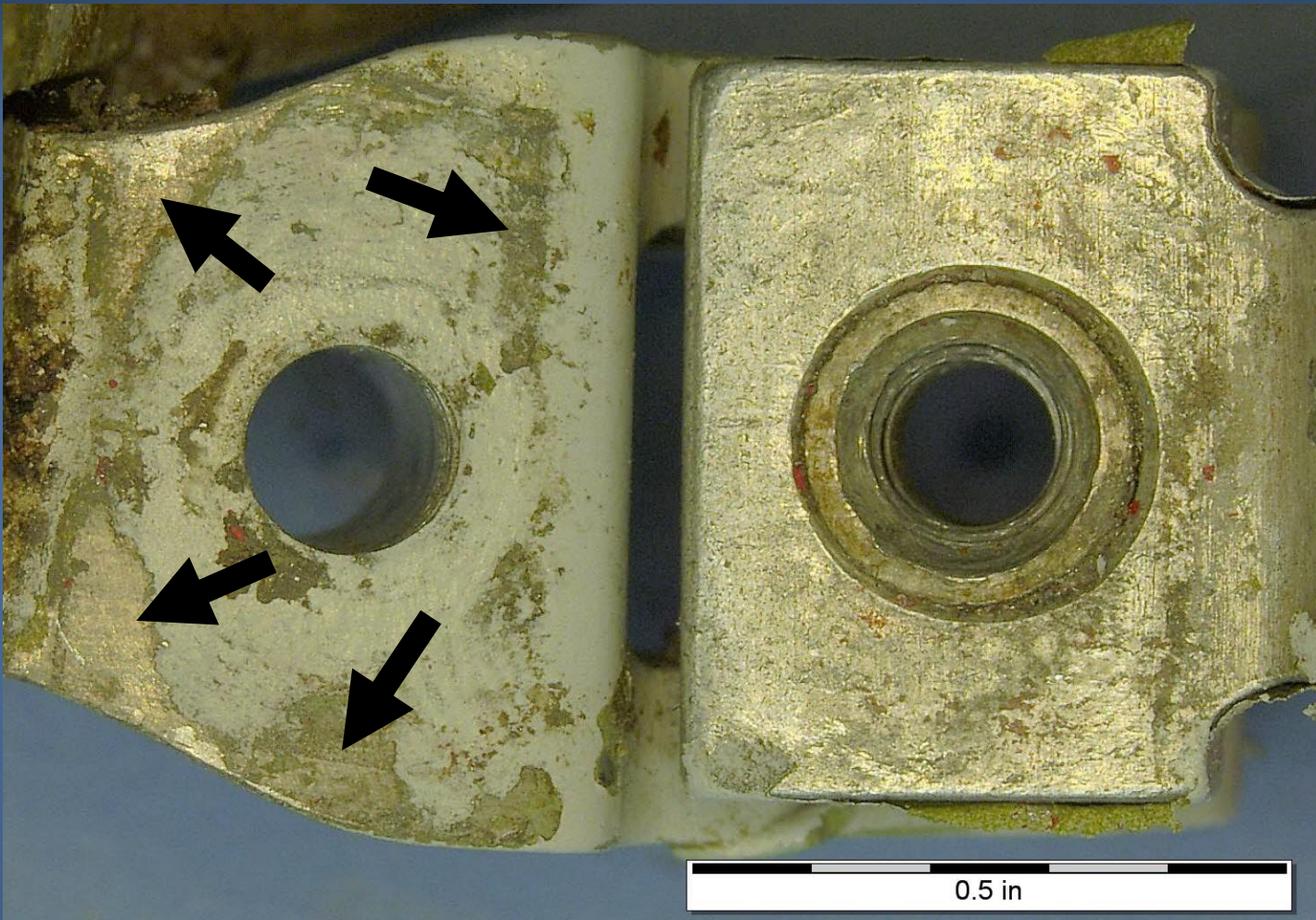
# Trim Tab Actuator



# Trim Tab Hinge



# Examination-Hinges



# Examination-Locknuts

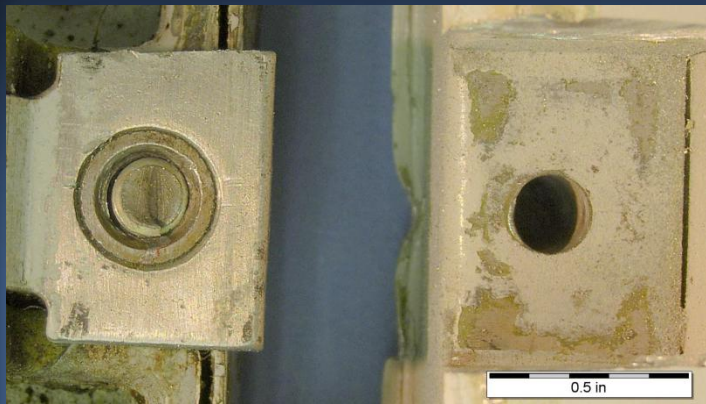


New locknut

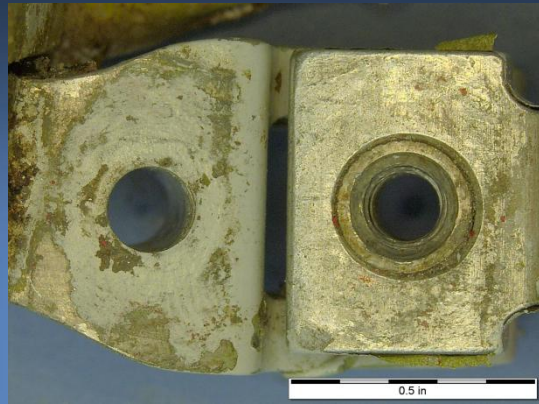


Ghost locknut

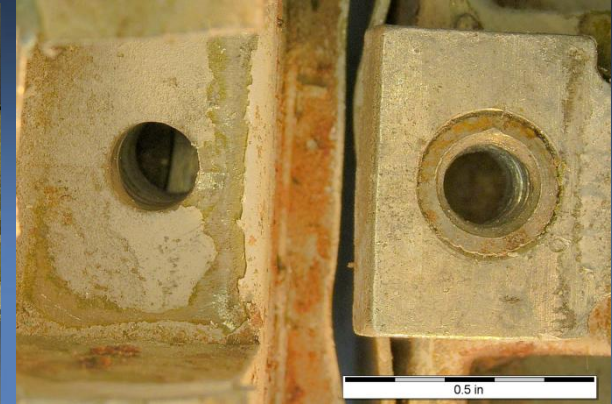
# Trim Tab Hinges



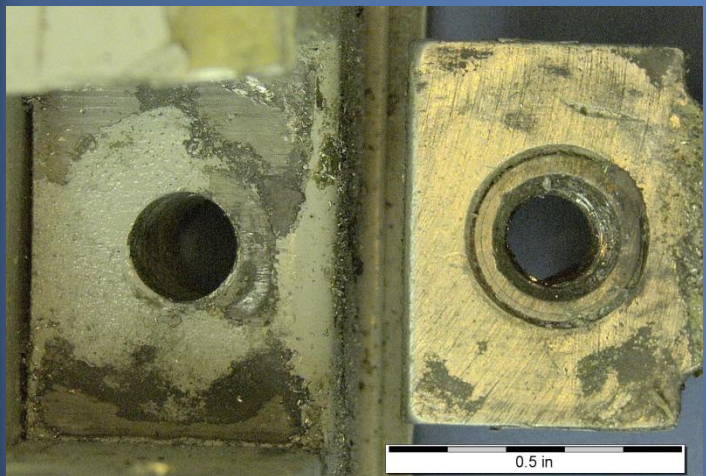
Left IB



Left CTR



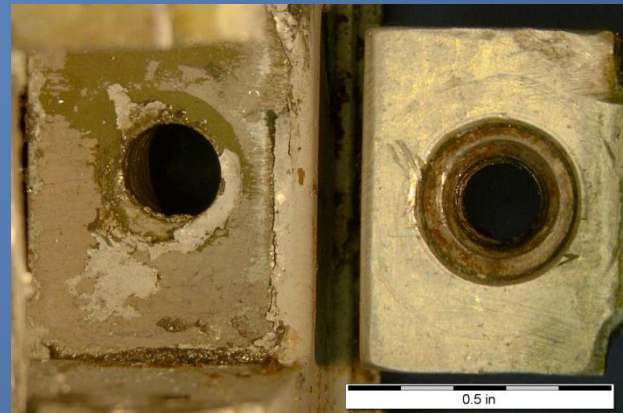
Left OB



Right IB



Right CTR



Right OB

# Locknuts



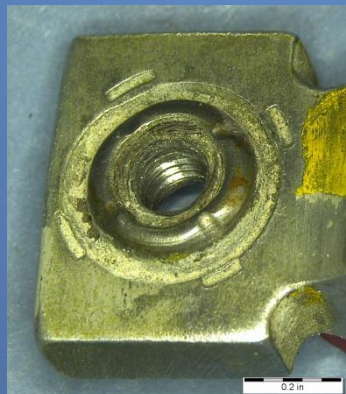
Left Tab CTR



Left Tab OB



Left Aileron IB



Left Aileron CTR



Left Aileron OB

# Examination-Links and Screw

- Link assemblies
  - Overload failure in bending
  - Compressive buckling deformation
  - Internal elevator damage
- Screw
  - Fatigue fracture 80%
  - Overload fracture 20%
  - Corrosion on fracture

# Flight Test History

- Owner informed FAA about boil-off system
- No notification of other major modifications
- FAA recommended 3 hours with 3 takeoffs/landings
- No evidence flight testing was completed
- No engineering analyses or substantiation
- 24.7 hours total time before 2011 races

# Indicators

- Fastest flight by about 35 knots
- Highest power settings
- Change in vibration amplitude and maximum load factor
- Tighten up loose trim tabs

# Structural Deformation-Fuselage

Photo by Florian Schmehl



# Structural Deformation-Canopy

Photo by Florian Schmehl



# Flutter

- Aeroelastic phenomenon
- Rapid periodic motion, oscillation or vibration
- Stable or unstable
- Range from “buzz” to violent destructive failure
- Speed and structural stiffness govern

# Flutter

## **Milestones in Flight History Dryden Flight Research Center**



## **PA-30 Twin Commanche Tail Flutter Test**

**April 5, 1966**

# Conclusions

- Loose screws reduced stiffness
- High race speeds
- Flutter of left trim tab
- Failure of left link assembly
- Uncommanded pitch up and high G
- Flutter of right trim tab
- Failure of right link assembly
- Separation of inboard left tab

# Initiators

- Pilot input
- Mach buffet
- Atmospheric turbulence
- Trim runaway
- Wake encounter
- Link assembly failure

# Probable Cause

The reduced stiffness of the elevator trim tab system that allowed aerodynamic flutter to occur at racing speeds. The reduced stiffness was a result of deteriorated locknut inserts that allowed the trim tab attachment screws to become loose and to initiate fatigue cracking in one screw sometime before the accident flight. Aerodynamic flutter of the trim tabs resulted in a failure of the left trim tab link assembly, elevator movement, high flight loads, and a loss of control.

Contributing to the accident were the undocumented and untested major modifications to the airplane's elevator trim control system and the pilot's operation of the airplane in the unique air racing environment without adequate flight testing.

# Safety Recommendations

- Federal Aviation Administration (FAA)
- National Air-racing Group (NAG) Unlimited Division
- Reno Air Racing Association (RARA)

## Recommendation A-12-8, FAA Guidance on Air Racing

- FAA Order 8900.1, Volume 3, Chapter 6, Section 3-151
- Advisory Circular (AC) 91-45C, Waivers: Aviation Events, Chapter 4
- FAA is revising Order and AC
- Open-Acceptable Response on July 25, 2012

# Recommendations A-12-9 and -13, Aircraft Modifications and Airworthiness

- Engineering evaluation and/or flight demonstrations
- NAG will request and review data for 2012
- RARA emphasizing for 2012 and reviewing procedures

## Recommendation A-12-10, Pre-race Technical Inspections

- System to track discrepancies
- New form for technical inspection
- All discrepancies signed off before flight on course

## Recommendations A-12-11 and -16, G-load Effects on Pilots

- High-G awareness training
- New training program and briefing
- All pilots required to attend briefing

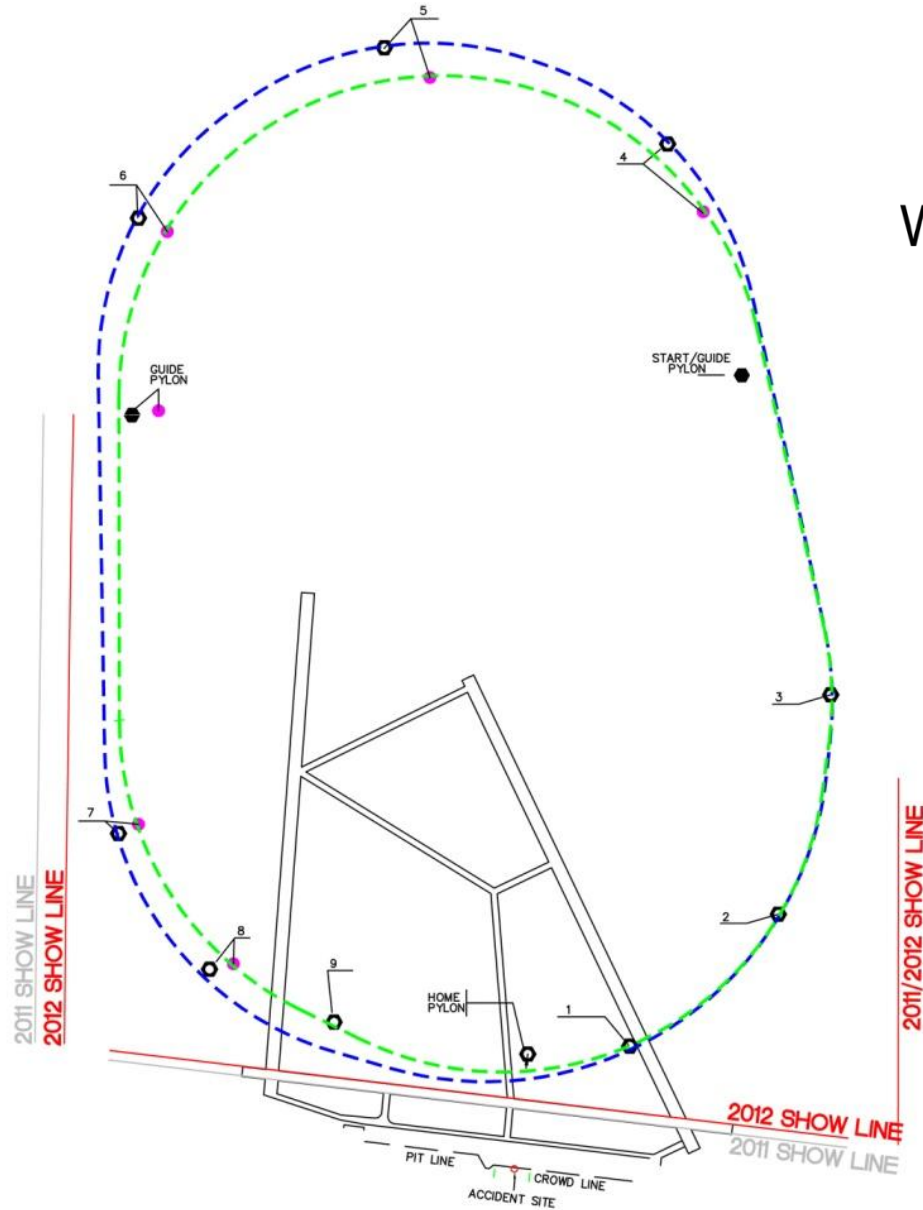
## Recommendations A-12-12 and -17, G-suits Feasibility

- Evaluate feasibility of G-suits when racing
- Determined not feasible for this type of racing

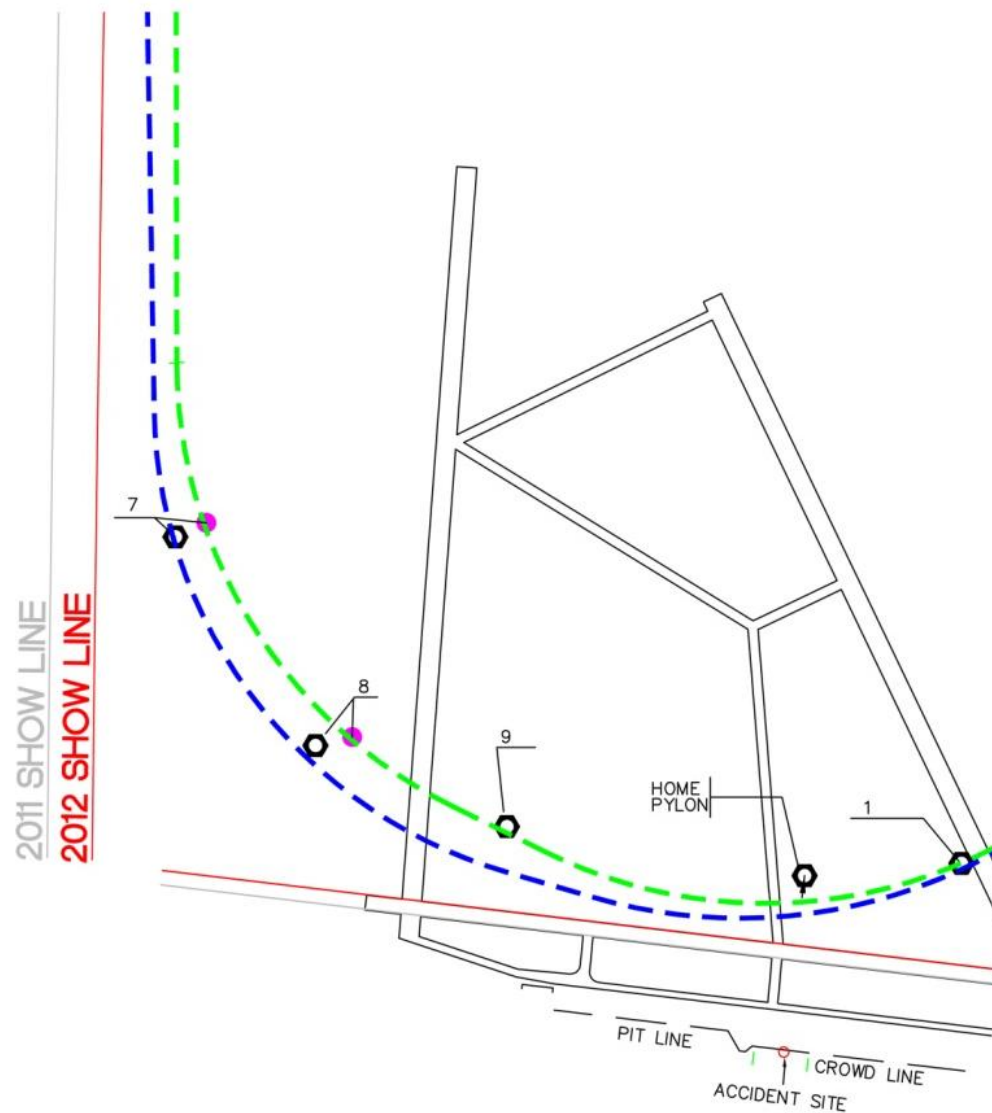
# Recommendations A-12-14 and -15, Race Course Design and Ramp Safety

- Evaluate course design
- Relocate fuel truck
- Install substantial barriers

# Course Changes



# Pylons 7, 8, and 9



# Recommendations A-12-14 and -15, Race Course Design and Ramp Safety

- Fuel truck moved 1.5 miles away
- Substantial barriers installed



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